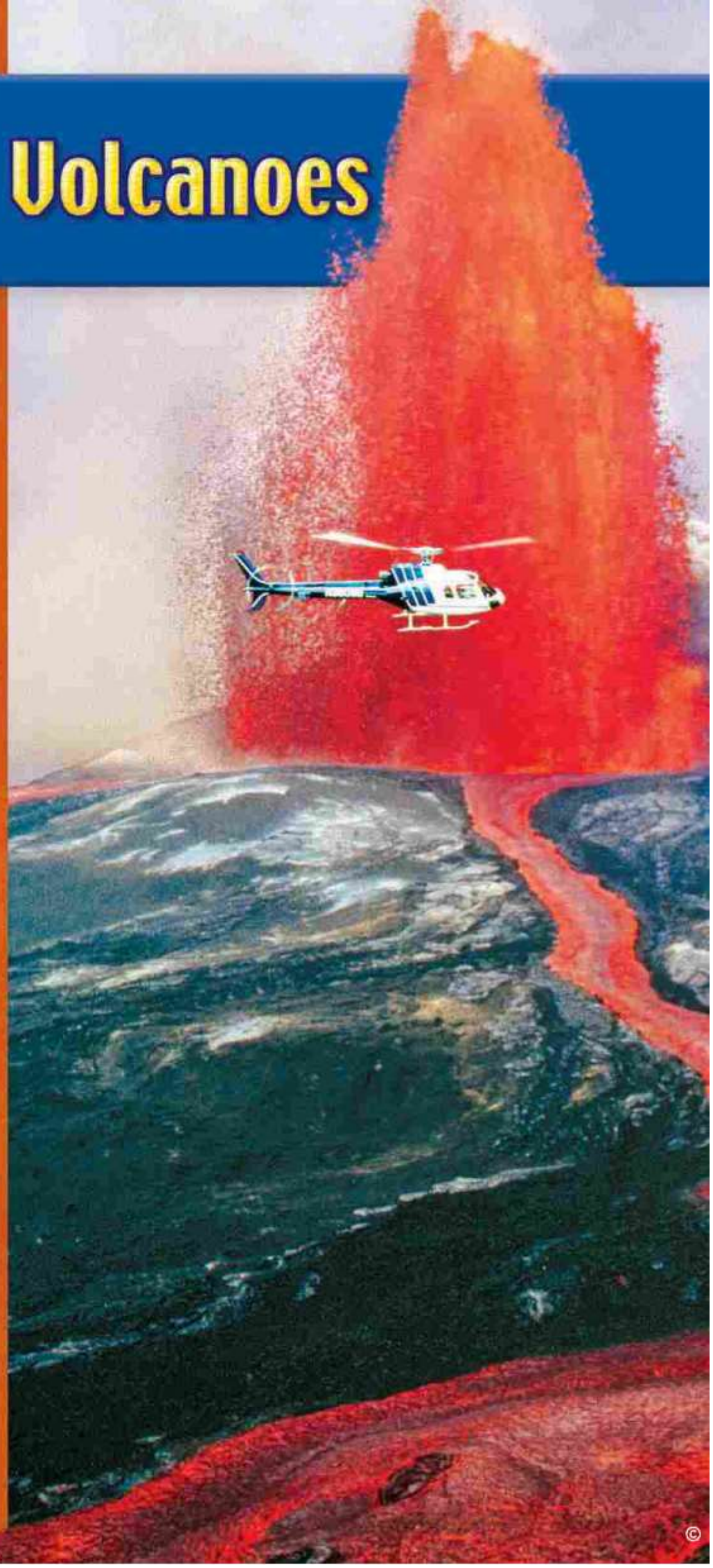
Chapter 6

Volcanoes



CALIFORNIA Standards Preview

S 6.1 Plate tectonics accounts for important features of Earth s surface and major geologic events. As a basis for understanding this concept:

d. Students know that earthquakes are sudden motions along breaks in the crust called faults and that volcanoes and fissures are locations where magma reaches the surface.

e. Students know major geologic events, such as earthquakes, volcanic eruptions, and mountain building, result from plate motions.

f. Students know how to explain major features of California geology (including mountains, faults, and volcanoes) in terms of plate tectonics.

S 6.2 Topography is reshaped by the weathering of rock and soil and by the transportation and deposition of sediment. As a basis for understanding this concept:

d. Students know earthquakes, volcanic eruptions, landslides, and floods change human and wildlife habitats.

S 6.7 Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

g. Interpret events by sequence and time from natural phenomena (e.g., the relative age of rocks and intrusions).

A spectacular lava fountain erupts from Mount Kilauea, a volcano in Hawaii. ►

Video Preview
Discovery Channel School
Volcanoes

Focus on the
BIG Idea

S 6.1.d

What causes volcanoes, and how do they change Earth's surface?

Check What You Know

You know that if you want to open a bottle of soda, you must do so carefully. Otherwise, the soda might spray out of the bottle as soon as you loosen the cap. What causes the soda to rush out with such force? How is this similar to what happens when a volcano erupts? Explain.

Build Science Vocabulary

The images shown here represent some of the key terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some key terms in this chapter.

Vocabulary Skill

Use Clues to Determine Meaning

Science textbooks often contain unfamiliar words. When you are reading, use clues to figure out what these words mean. First look for clues in the word itself. Then look at the surrounding words, sentences, and paragraphs.

Look at the clues to the meaning of *hot spot* in the following text.

Unfamiliar words

Hot spot is the subject of the sentence.

Definition, follows boldface

Some volcanoes result from hot spots in Earth's mantle. A **hot spot** is an area where material from within the mantle rises and then melts. A volcano forms above a hot spot when the hot material erupts through the crust and reaches the surface.

Explanation

A hot spot in the ocean floor can gradually form a series of volcanic mountains. For example, the Hawaiian Islands formed one by one over millions of years as the Pacific plate drifted over a hot spot.

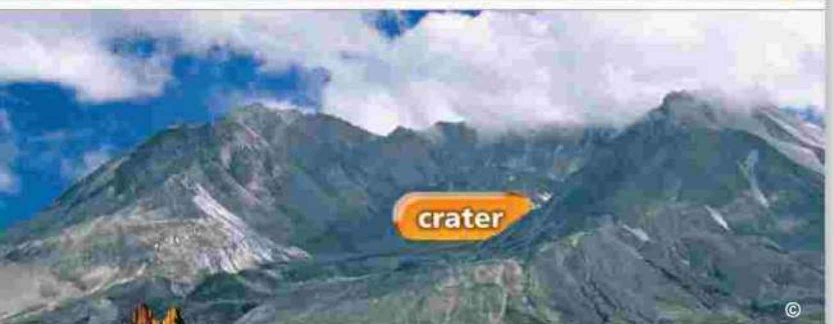
Example

Apply It!

Review the clues to the meaning of *hot spot*. Then complete the following.

1. What clue tells you that *hot spot* might be followed by a definition?
2. What example helps you understand hot spots?

As you come across an unfamiliar word in this chapter, look for clues to its meaning.



Chapter 6 Vocabulary

Section 1 (page 216)
volcano
magma
lava
Ring of Fire
island arc
hot spot

Section 2 (page 221)
magma chamber
pipe
vent
lava flow
crater
silica
pyroclastic flow
dormant
extinct
geyser

Section 3 (page 229)
shield volcano
cinder cone
composite volcano
caldera
volcanic neck
dike
sill
intrusion
batholith

Section 4 (page 235)
basin
Central Valley

Interactive Textbook
Build Science Vocabulary *Online*
Use interactive flashcards

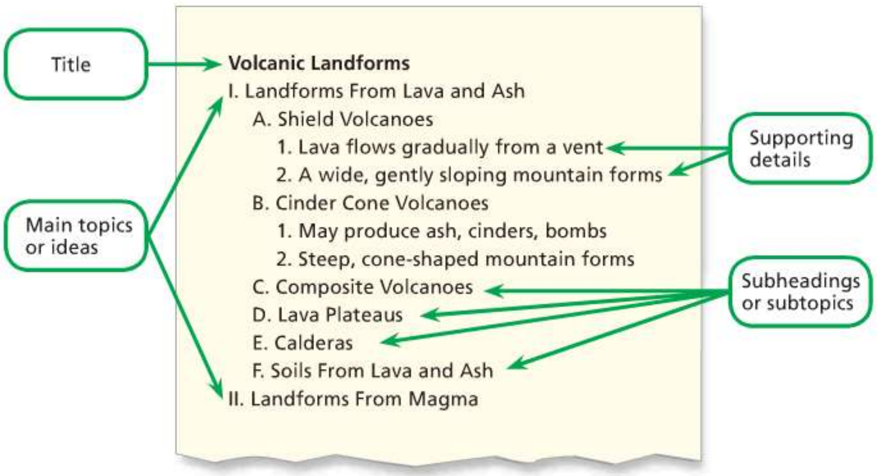
How to Read Science

Reading Skill

Create Outlines

You have learned to use headings and to identify main ideas and details to guide you as you read. An outline uses these skills to show the relationship between main ideas and supporting details.

An outline usually is set up like the one below. Roman numerals show the main topics or headings. Capital letters show the subheadings. Numbers show supporting details and key terms.



Apply It!

Answer each of the following questions.

1. What are the most important ideas in this outline?
2. What details support the subheading Shield Volcanoes?

Copy the outline above into your notebook. Use the headings, subheadings, and key terms to help you select information to complete the outline for Landforms From Magma in Section 3. Create an outline for Kinds of Volcanic Eruptions in Section 2.

Standards Investigation

S 6.2.d

Volcanoes and People

The eruptions of a volcano can be dangerous. Yet volcanoes and people have been closely connected throughout history. People often live near volcanoes because of the benefits they offer, from rich soil to minerals to hot springs. In this investigation, you will research the people living in a volcanic region.

Your Goal

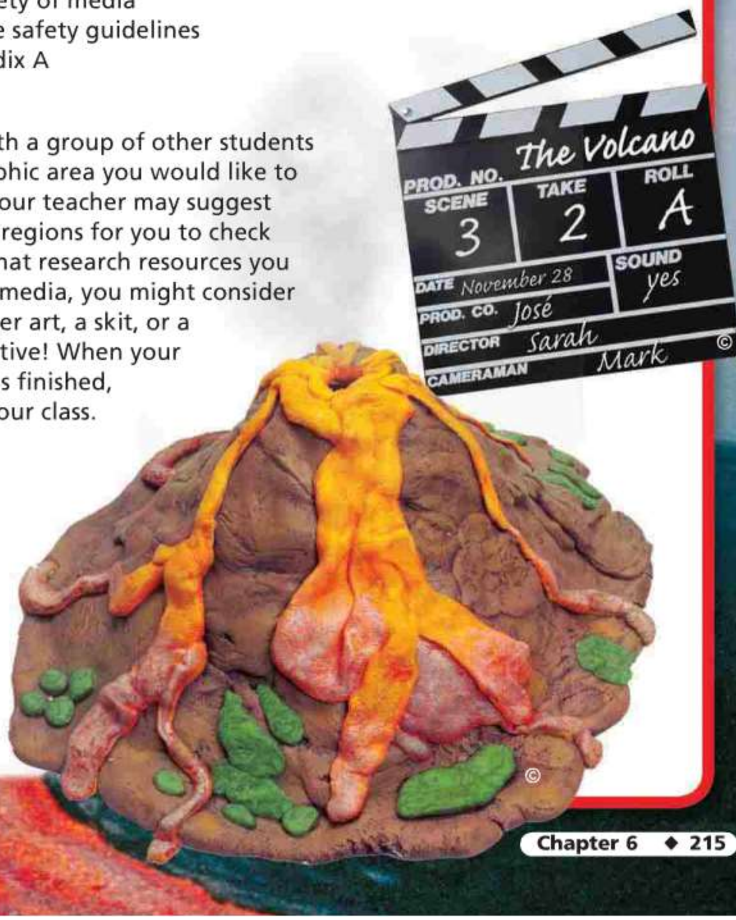
To make a documentary about life in a volcanic region

Your documentary must

- describe the type of volcano you chose and give its history
- focus on one topic, such as how people have benefited from living near the volcano or how people include the volcano in their art and stories
- use a variety of media
- follow the safety guidelines in Appendix A

Plan It!

Brainstorm with a group of other students which geographic area you would like to learn about. Your teacher may suggest some volcanic regions for you to check out. Decide what research resources you will need. For media, you might consider video, computer art, a skit, or a mural. Be creative! When your documentary is finished, present it to your class.



Section 1

Volcanoes and Plate Tectonics

CALIFORNIA Standards Focus

S 6.1 Plate tectonics accounts for important features of Earth's surface and major geologic events. As a basis for understanding this concept:

e. Students know major geologic events, such as earthquakes, volcanic eruptions, and mountain building, result from plate motions.

- Where are most of Earth's volcanoes found?
- How do hot spot volcanoes form?

Key Terms

- volcano
- magma
- lava
- Ring of Fire
- island arc
- hot spot

Lab zone Standards Warm-Up

Where Are Volcanoes Found on Earth's Surface?

1. Look at the map of Earth's Active Volcanoes in Figure 2. What symbols are used to represent volcanoes? What other symbols are shown on the map?
2. Do the locations of the volcanoes form a pattern? Do the volcanoes seem related to any other features on Earth's surface?

Think About It

Developing Hypotheses Develop a hypothesis to explain where Earth's volcanoes are located.

In 2002, Mount Etna erupted in glowing fountains and rivers of molten rock. Located on the island of Sicily in the Mediterranean Sea, Mount Etna is Europe's largest volcano. Over the last 2,500 years, it has erupted often. The ancient Greeks believed that Mount Etna was one home of Hephaestus, the Greek god of fire. Beneath the volcano was the forge where Hephaestus made beautiful metal objects for the other Greek gods.

The eruption of a volcano is among the most awe-inspiring events on Earth. A **volcano** is a weak spot in the crust where molten material, or magma, comes to the surface. **Magma** is a molten mixture of rock-forming substances, gases, and water from the mantle. When magma reaches the surface, it is called **lava.** After lava has cooled, it forms solid rock. Lava released during volcanic activity builds up Earth's surface.

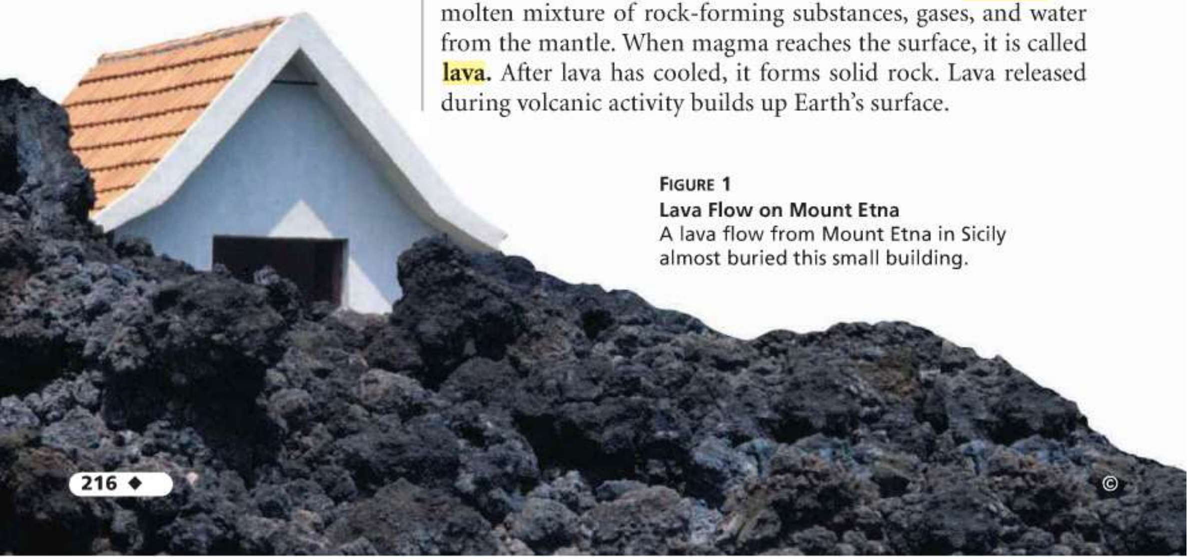


FIGURE 1
Lava Flow on Mount Etna
A lava flow from Mount Etna in Sicily almost buried this small building.

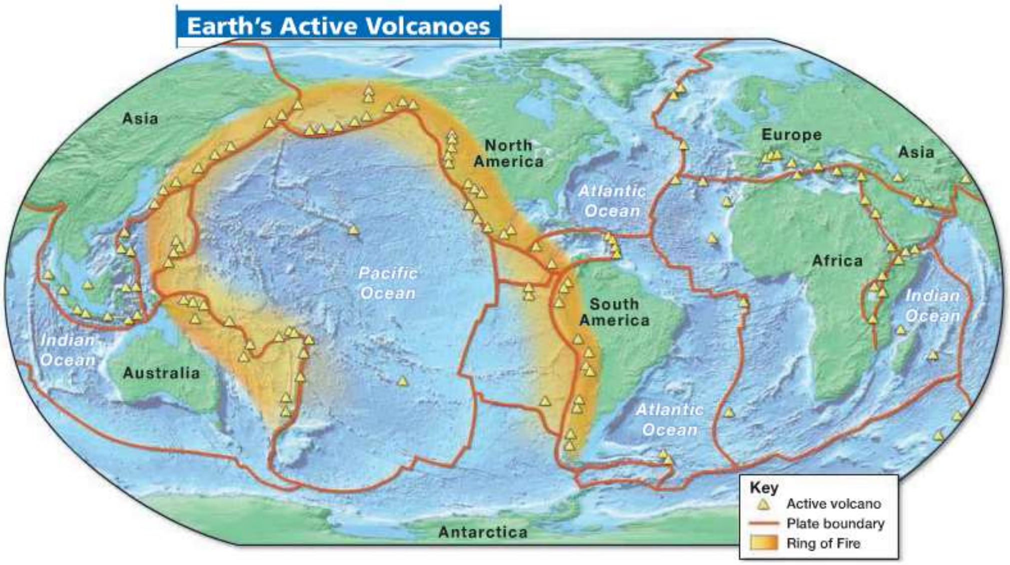


FIGURE 2
Many of Earth's volcanoes are located along the boundaries of tectonic plates. The belt of volcanoes that circles the Pacific Ocean is called the Ring of Fire.
Observing *What other regions have a large number of volcanoes?*

Volcanoes and Plate Boundaries

There are about 600 active volcanoes on land. Many more lie beneath the sea, where it is difficult for scientists to observe and map them. Figure 2 shows the location of some of Earth's major volcanoes. Notice how volcanoes occur in belts that extend across continents and oceans. One major volcanic belt is the **Ring of Fire,** formed by the many volcanoes that rim the Pacific Ocean.

Volcanic belts form along the boundaries of Earth's plates. At plate boundaries, huge pieces of the crust spread apart or collide. As a result, the crust often fractures, allowing magma to reach the surface. Most volcanoes form along spreading boundaries such as mid-ocean ridges and along colliding boundaries where subduction takes place. For example, Mount Etna formed near the boundary of the Eurasian and African plates.

Spreading Boundaries Volcanoes form along the mid-ocean ridges, which mark spreading boundaries. Recall that ridges are long, underwater mountain ranges that sometimes have a rift valley down their center. Along the rift valley, lava pours out of cracks in the ocean floor, gradually building new mountains. Volcanoes also form along spreading boundaries on land. For example, there are several large volcanoes along the Great Rift Valley in East Africa.

Go Online
PLANET DIARY
For: More on volcanoes
Visit: PHSchool.com
Web Code: cfd-1031

Colliding Boundaries Many volcanoes form near colliding boundaries where oceanic plates return to the mantle. Volcanoes may form where two oceanic plates collide or where an oceanic plate collides with a continental plate. Figure 3 shows how colliding plates produce volcanoes.

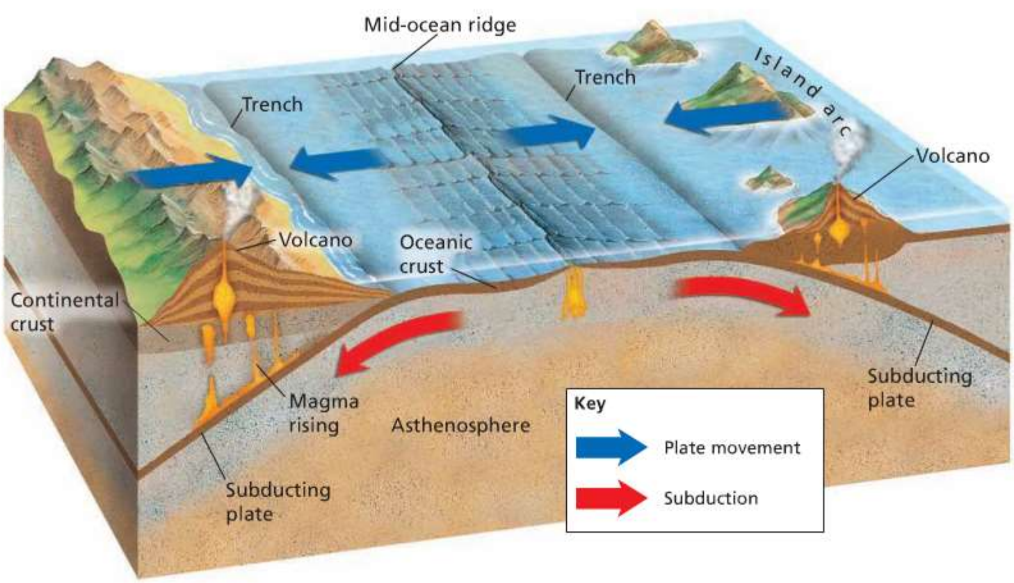
Many volcanoes occur near boundaries where two oceanic plates collide. Through subduction, the older, denser plate sinks beneath a deep-ocean trench into the mantle. Some of the rock above the subducting plate melts and forms magma. Because the magma is less dense than the surrounding rock, it rises toward the surface. Eventually, the magma breaks through the ocean floor, creating volcanoes.

The resulting volcanoes create a string of islands called an **island arc.** The curve of an island arc echoes the curve of its deep-ocean trench. Major island arcs include Japan, New Zealand, Indonesia, the Philippines, the Aleutians, and the Caribbean islands.

Volcanoes also occur where an oceanic plate is subducted beneath a continental plate. Collisions of this type produced the volcanoes of the Andes in South America and the volcanoes of Northern California, Oregon, and Washington.

Reading Checkpoint How did the volcanoes in the Andes Mountains form?

FIGURE 3
Volcanoes at Colliding Boundaries
Volcanoes often form where two oceanic plates collide or where an oceanic plate collides with a continental plate. In both situations, an oceanic plate sinks beneath a trench. Rock above the plate melts to form magma, which later erupts as lava.



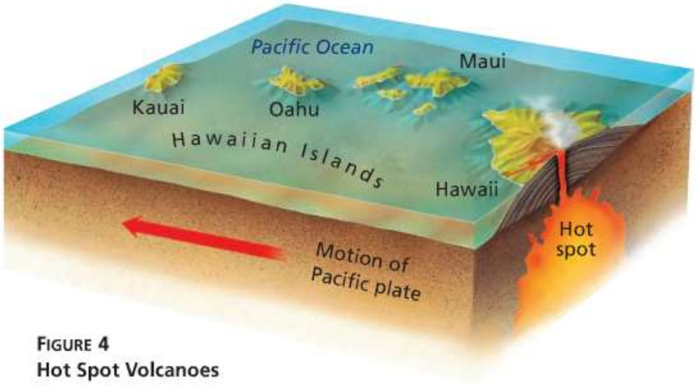


FIGURE 4
Hot Spot Volcanoes
Eventually, the Pacific plate's movement will carry the island of Hawaii away from the hot spot.
Inferring *Which island on the map formed first?*

Hot Spot Volcanoes

Some volcanoes result from "hot spots" in Earth's mantle. A **hot spot** is an area where material from deep within the mantle rises and then melts, forming magma. **A volcano forms above a hot spot when magma erupts through the crust and reaches the surface.** Some hot spot volcanoes lie in the middle of plates far from any plate boundaries. Other hot spots occur on or near plate boundaries.

A hot spot in the ocean floor can gradually form a series of volcanic mountains. For example, the Hawaiian Islands formed, one by one, over millions of years as the Pacific plate drifted over a hot spot. Hot spots can also form under the continents. Yellowstone National Park in Wyoming marks a hot spot under the North American plate.

Lab zone Try This Activity

Hot Spot in a Box

1. Fill a plastic box half full of cold water. This represents the mantle.
2. Mix red food coloring with hot water in a small, narrow-necked bottle to represent magma.
3. Hold your finger over the mouth of the bottle as you place the bottle in the center of the box. The mouth of the bottle must be under water.
4. Float a flat piece of plastic foam on the water above the bottle to model a tectonic plate.
5. Take your finger off the bottle and observe what happens to the "magma."

Making Models Move the plastic foam slowly along. Where does the magma touch the "plate"? How does this model a hot spot volcano?

Section 1 Assessment

S 6.1.e: E-LA: Reading 6.1.4, Writing 6.2.2

Vocabulary Skill **Use Clues to Determine Meaning**
Reread the paragraph on island arcs, under the heading Colliding Boundaries. What are some examples of island arcs?

Reviewing Key Concepts

HINT HINT HINT
1. a. **Defining** What is a volcano?
   b. **Reviewing** Where are most volcanoes located?
   c. **Relating Cause and Effect** What causes volcanoes to form at a spreading plate boundary?

HINT HINT HINT
2. a. **Defining** What is a hot spot?
   b. **Summarizing** How does a hot spot volcano form?
   c. **Predicting** What features form at a hot spot?

Writing in Science

Travel Brochure As a travel agent, you are planning a Pacific Ocean cruise that will visit volcanoes in the Ring of Fire and Hawaii. Write a travel brochure describing the types of volcanoes the group will see and explaining why the volcanoes formed where they did.

Lab zone Skills Lab
Guided Inquiry

S 6.1.e

Mapping Earthquakes and Volcanoes

Problem
Is there a pattern in the locations of earthquakes and volcanoes?

Skills Focus
interpreting data

Procedure

1. Use the information in the table to mark the location of each earthquake on a world map. Use a colored pencil to draw a letter E inside a circle at each earthquake location.
2. Use a pencil of a second color to mark the volcanoes on the world map. Indicate each volcano with the letter V inside a circle.
3. Use a third pencil to lightly shade the areas in which earthquakes are found.
4. Use a fourth colored pencil to lightly shade the areas in which volcanoes are found.

Earthquakes and Volcanoes

Earthquakes		Volcanoes	
Longitude	Latitude	Longitude	Latitude
122° W	37° N	150° W	60° N
110° E	5° S	70° W	35° S
77° W	4° S	155° W	19° N
88° E	23° N	61° W	15° N
121° E	14° S	105° W	20° N
34° E	7° N	75° W	0°
74° W	44° N	122° W	40° N
70° W	30° S	120° E	15° N
10° E	45° N	60° E	30° N
85° W	13° N	160° E	55° N
125° E	23° N	37° E	3° S
30° E	35° N	145° E	40° N
140° E	35° N	120° E	10° S
102° W	18° N	14° E	41° N
75° E	28° N	105° E	5° S
150° W	61° N	35° E	15° N
68° W	47° S	70° W	30° S
175° E	41° S	175° E	39° S
143° E	3° S	168° W	53° N
160° E	53° N	16° W	64° N

Analyze and Conclude

1. **Interpreting Data** How are earthquakes distributed on the map? Are they scattered evenly or concentrated in zones?
2. **Interpreting Data** How are volcanoes distributed? Are they scattered evenly or concentrated in zones?
3. **Inferring** From your data, what can you infer about the relationship between earthquakes and volcanoes?
4. **Communicating** Suppose the locations of additional earthquakes and volcanoes were added to the map. Would the overall pattern of earthquakes and volcanoes change? Explain in writing why you think the pattern would or would not change.

More to Explore

Pick one earthquake and one volcanic eruption to investigate. (You can use the list of earthquakes in Figure 19 on page 198 and the Science & History timeline on volcanoes on pages 226–227). Plot and label the events on the map you just made. Research how the events relate to plate motions and how powerful they were. Report your findings to your class.

Section 2

Volcanic Eruptions

California Standards Focus

S 6.1.d Students know that earthquakes are sudden motions along breaks in the crust called faults and that volcanoes and fissures are locations where magma reaches the surface.

S 6.2.d Students know earthquakes, volcanic eruptions, landslides, and floods change human and wildlife habitats.

- What happens when a volcano erupts?
- What are the two types of volcanic eruptions?
- What are a volcano's stages of activity?

Key Terms

- magma chamber
- pipe
- vent
- lava flow
- crater
- pyroclastic flow
- dormant
- extinct
- geyser

Lab zone Standards Warm-Up

What Are Volcanic Rocks Like?

Volcanoes produce lava, which hardens into rock. Two of these rocks are pumice and obsidian.

1. Observe samples of pumice and obsidian with a hand lens.
2. How would you describe the texture of the pumice? What could have caused this texture?
3. Observe the surface of the obsidian. How does the surface of the obsidian differ from pumice?

Pumice

Obsidian

Think It Over

Developing Hypotheses What could have produced the difference in texture between the two rocks? Explain your answer.

In Hawaii, there are many myths about Pele (PAY lay), the fire goddess of volcanoes. According to legend, Pele lives in the depths of Hawaii's erupting volcanoes. When Pele is angry, she causes a volcanic eruption. One result of an eruption is "Pele's hair," a fine, threadlike rock formed by lava. Pele's hair forms when lava sprays out of the ground like water from a fountain. As it cools, the lava stretches and hardens into thin strands, as shown in Figure 5.

Where does this lava come from? Lava begins as magma, which usually forms in the asthenosphere. The materials of the asthenosphere are under great pressure. Liquid magma is less dense than the solid material around it. Therefore, magma flows upward into any cracks in the rock above. As magma rises, it sometimes becomes trapped beneath layers of rock. But if an opening in weak rock allows the magma to reach the surface, a volcano forms.

FIGURE 5
Pele's Hair
Pele's hair is a type of rock formed from lava. Each strand is as fine as spun glass.

Lab zone **Try This Activity**

Gases in Magma

This activity models the gas bubbles in a volcanic eruption.

1. In a 1- or 2-liter plastic bottle, mix 10 g of baking soda into 65 mL of water.
2. Put about six raisins in the water.
3. While swirling the water and raisins, add 65 mL of vinegar and stir vigorously.
4. Once the liquid stops moving, observe the raisins.

Making Models What happens after you add the vinegar? What do the raisins and bubbles represent? How is this model similar to the way magma behaves in a volcano?

Magma Reaches Earth's Surface

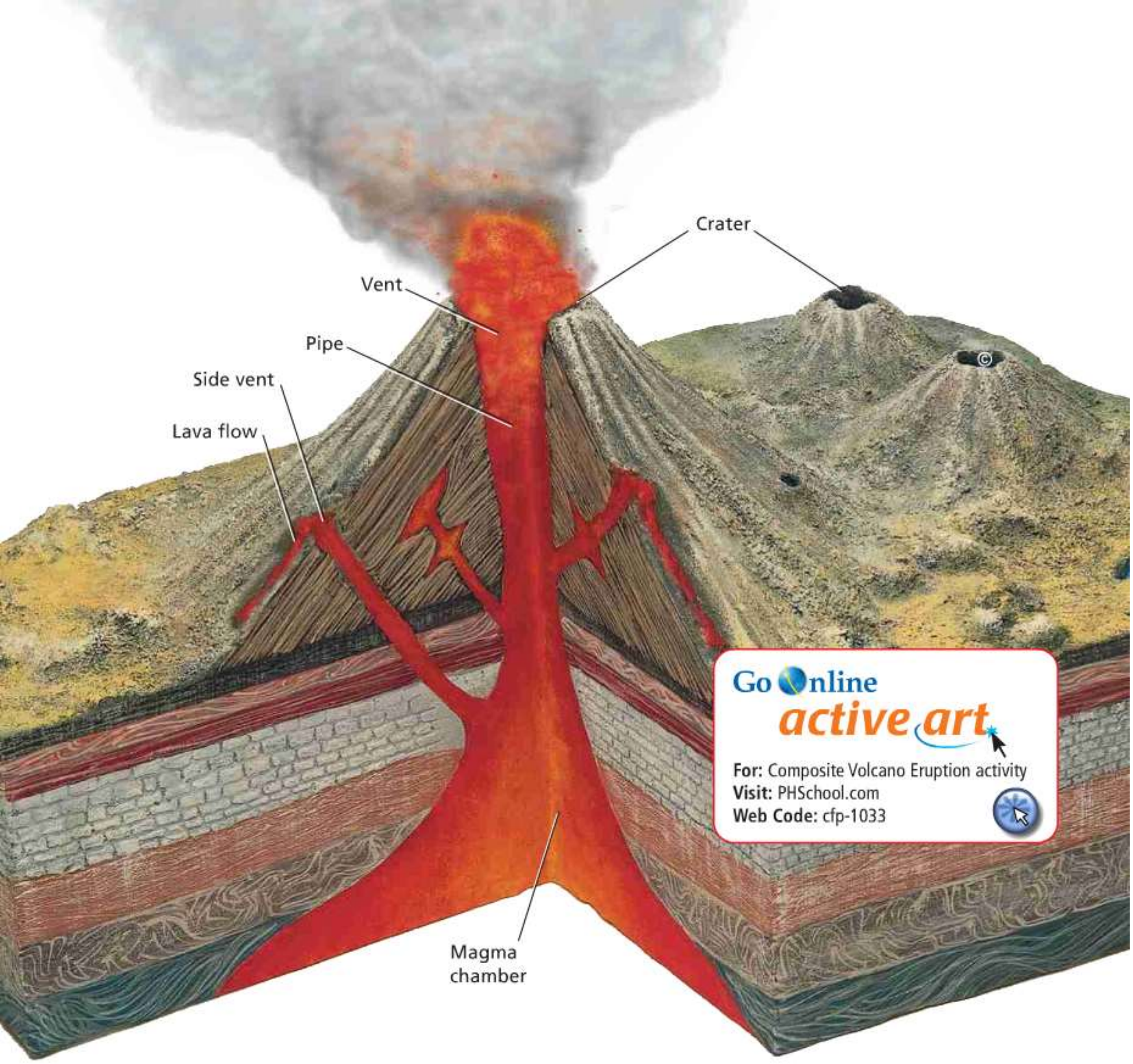
A volcano is more than a large, cone-shaped mountain. Inside a volcano is a system of passageways through which magma moves.

Inside a Volcano All volcanoes have a pocket of magma beneath the surface and one or more cracks through which the magma forces its way. Beneath a volcano, magma collects in a pocket called a **magma chamber.** The magma moves upward through a **pipe,** a long tube in the ground that connects the magma chamber to Earth's surface. You can see these features in Figure 7.

Molten rock and gas leave the volcano through an opening called a **vent.** Often, there is one central vent at the top of a volcano. However, many volcanoes also have other vents that open on the volcano's sides. A **lava flow** is the area covered by lava as it pours out of a vent. A **crater** is a bowl-shaped area that may form at the top of a volcano around the central vent.

A Volcanic Eruption What pushes magma to the surface? The explosion of a volcano is similar to the soda water bubbling out of a warm bottle of soda pop. You cannot see the carbon dioxide gas in a bottle of soda pop because it is dissolved in the liquid. But when you open the bottle, pressure is released. The carbon dioxide expands and forms bubbles, which rush to the surface. Like the carbon dioxide in soda pop, dissolved gases are trapped in magma. These dissolved gases are under tremendous pressure.

FIGURE 6
Lava Burp
During an eruption of Mount Kilauea, the force of a bursting gas bubble pushes up a sheet of red-hot lava.



Go Online active art
For: Composite Volcano Eruption activity
Visit: PHSchool.com
Web Code: cfp-1033

As magma rises toward the surface, the pressure of the surrounding rock on the magma decreases. The dissolved gases begin to expand, forming bubbles. As pressure falls within the magma, the size of the gas bubbles increases greatly. These expanding gases exert an enormous force. **When a volcano erupts, the force of the expanding gases pushes magma from the magma chamber through the pipe until it flows or explodes out of the vent.** Once magma escapes from the volcano and becomes lava, the remaining gases bubble out.

Reading Checkpoint **What happens to the pressure in magma as the magma rises toward the surface?**

FIGURE 7
A Volcano Erupts
A volcano forms where magma breaks through Earth's crust and lava flows over the surface.
Interpreting Diagrams *What part of a volcano connects the vent with the magma chamber?*

FIGURE 8
Pahoehoe and Aa
Both pahoehoe and aa can come from the same volcano. Pahoehoe flows easily and hardens into a rippled surface. Aa hardens into rough chunks.

Kinds of Volcanic Eruptions

Some volcanic eruptions occur gradually. Others are dramatic explosions. **Geologists classify volcanic eruptions as quiet or explosive.** The properties of magma determine how a volcano erupts. Whether an eruption is quiet or explosive depends on the magma's silica content and whether the magma is thin and runny or thick and sticky. **Silica** is a material found in magma that is formed from the elements oxygen and silicon.

Quiet Eruptions A volcano erupts quietly if its magma is low in silica. Low-silica magma is thin and runny and flows easily. The gases in the magma bubble out gently. Low-silica lava oozes quietly from the vent and can flow for many kilometers.

Quiet eruptions can produce two different types of lava that differ in temperature. Pahoehoe (pah HOH ee hoh ee) is fast-moving, hot lava that is thin and runny. The surface of a lava flow formed from pahoehoe looks like a solid mass of wrinkles and ropelike coils. Lava that is cooler and slower-moving is called aa (AH ah). Aa is thicker than pahoehoe. When aa hardens, it forms a rough surface consisting of jagged lava chunks.

The Hawaiian Islands were formed from quiet eruptions. On the Big Island of Hawaii, lava pours out of the crater on Mount Kilauea. But lava also flows out of long cracks, called fissures, on the volcano's sides. Quiet eruptions have built up the Big Island over hundreds of thousands of years.

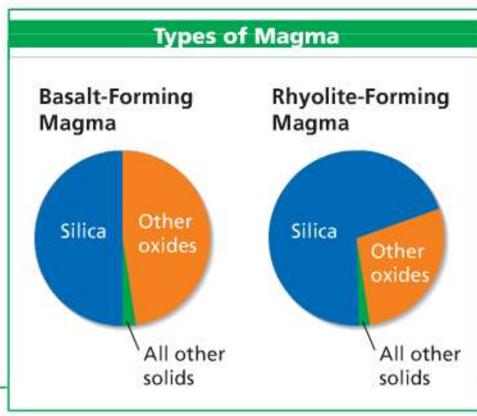
Reviewing Math: Mathematical Reasoning 6.2.4

Math Analyzing Data

Magma Composition

Magma varies in composition and is classified according to the amount of silica it contains. The graphs show the average composition of two types of magma. Use the graphs to answer the questions.

1. **Reading Graphs** Study both graphs. What materials make up both types of magma?
2. **Reading Graphs** Which type of magma has more silica? About how much silica does this type of magma contain?
3. **Estimating** A third type of magma has a silica content that is halfway between that of the other two types. About how much silica does this magma contain?
4. **Predicting** What type of magma would be more thick and sticky? Explain.



Explosive Eruptions A volcano erupts explosively if its magma is high in silica. High-silica magma is thick and sticky. It builds up in the volcano's pipe, plugging it like a cork in a bottle. Dissolved gases, including water vapor, cannot escape from the thick magma. The trapped gases build up pressure until they explode. The erupting gases and steam push the magma out of the volcano with incredible force. That's what happened during the eruption of Mount St. Helens, shown in Figure 9.

An explosive eruption breaks lava into fragments that quickly cool and harden into pieces of different sizes. The smallest pieces are volcanic ash—fine, rocky particles as small as a speck of dust. Pebble-sized particles are called cinders. Larger pieces, called bombs, may range from the size of a baseball to the size of a car. A **pyroclastic flow** (py roh KLAS tik) is a type of explosive eruption that hurls out a mixture of hot gases, ash, cinders, and bombs.

Pumice and obsidian, which you observed if you did the Standards Warm-Up activity, form from high-silica lava. Obsidian forms when lava cools very quickly, giving it a smooth, glossy surface like glass. Pumice forms when gas bubbles are trapped in fast-cooling lava, leaving spaces in the rock.

FIGURE 9
An Explosive Eruption
Mount St. Helens in Washington State erupted at 8:30 A.M. on May 18, 1980. The explosion blew off the top of the mountain.
Relating Cause and Effect *Why did Mount St. Helens erupt so explosively?*

Reading Checkpoint **What is a pyroclastic flow?**

Volcano Hazards Although quiet eruptions and explosive eruptions produce different hazards, both types of eruption can cause damage far from the crater's rim.

During a quiet eruption, lava flows from vents, setting fire to, and then burying, everything in its path. A quiet eruption can cover large areas with a thick layer of lava.

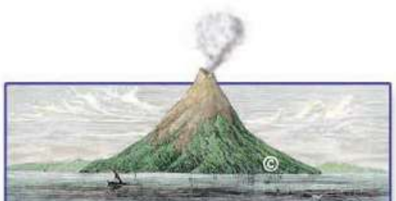
During an explosive eruption, a volcano can belch out hot clouds of deadly gases as well as ash, cinders, and bombs. Volcanic ash can bury entire towns. If it becomes wet, the heavy ash can cause roofs to collapse. If a jet plane sucks ash into its engine, the engine may stall. Eruptions can cause landslides and avalanches of mud, melted snow, and rock. The Science and History timeline shows the effects of several explosive eruptions.

Reading Checkpoint **How does volcanic ash cause damage?**

Science and **History**

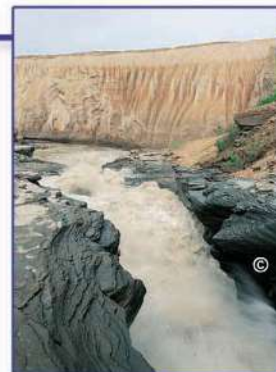
The Power of Volcanoes

Within the last 150 years, major volcanic eruptions have greatly affected the land and people around them.



1883 Krakatau
The violent eruption of Krakatau volcano in Indonesia threw 18 cubic kilometers of ash skyward. The blast was heard 5,000 kilometers away.

1902 Mount Pelée
Mount Pelée, a Caribbean volcano, spewed out a burning cloud of hot gas and pyroclastic flows. The cloud killed 29,000 residents of St. Pierre, a city on the volcano's flank. Only two people survived.



1912 Mount Katmai
Today, a river in Alaska cuts through the thick layer of volcanic ash from the eruption of Mount Katmai.

1850 1875 1900

Stages of Volcanic Activity

The activity of a volcano may last from less than a decade to more than 10 million years. Geologists try to determine a volcano's past and whether the volcano will erupt again.

Life Cycle of a Volcano **Geologists often use the terms *active, dormant,* or *extinct* to describe a volcano's stage of activity.** An active, or live, volcano is one that is erupting or has shown signs that it may erupt in the near future. A dormant, or sleeping, volcano is like a sleeping bear. Scientists expect a **dormant** volcano to awaken in the future and become active. An **extinct,** or dead, volcano is unlikely to erupt again.

In California, Lassen Peak and Mount Shasta are considered active volcanoes. Lassen Peak last erupted in 1917, and Mount Shasta erupted during the late 1700s. Craters near Long Valley on the eastern side of the Sierras are dormant but could become active again.

Writing in Science

Research and Write People have written eyewitness accounts of famous volcanic eruptions. Research one of the eruptions in the timeline. Then write a letter describing what someone observing the eruption might have seen.

1980 Mount St. Helens
When Mount St. Helens in Washington exploded, it blasted one cubic kilometer of volcanic material skyward.

1991 Mount Pinatubo
Pinatubo in the Philippines spewed out huge quantities of ash that rose high into the atmosphere and buried nearby areas.

2002 Mount Etna
Bulldozers constructed a wall against a scalding river of lava creeping down the slopes of Mount Etna in Sicily.

1950 | 1975 | 2000

FIGURE 10
A Geyser Erupts
Old Faithful, a geyser in Yellowstone National Park, erupts about every 33 to 93 minutes.

Hot Springs and Geysers Hot springs and geysers are often found in areas of present or past volcanic activity. A hot spring forms when water deep underground is heated by a nearby body of magma or by hot rock. The hot water rises to the surface and collects in a natural pool. Sometimes, rising hot water and steam become trapped in a narrow crack. Pressure builds until the mixture suddenly sprays above the surface as a geyser. A **geyser** (GY zur) is a fountain of water and steam that erupts from the ground.

Monitoring Volcanoes Geologists use instruments to detect changes in and around a volcano. These changes may give warning a short time before a volcano erupts. But geologists cannot be certain about the type of eruption or how powerful it will be.

Geologists use tiltmeters and other instruments to detect slight surface changes in elevation and tilt caused by magma moving underground. They monitor any gases escaping from the volcano. A temperature increase in underground water may be a sign that magma is nearing the surface. Geologists also monitor the many small earthquakes that occur around a volcano before an eruption. The upward movement of magma triggers these quakes.

Section 2 Assessment

S 6.1.d, 6.2.d; E-LA: Reading 6.2.4, Writing 6.2.2

Target Reading Skill Create Outlines
Complete your outline for the section Volcanic Eruptions. What are three important details that you included under the heading Life Cycle of a Volcano?

Reviewing Key Concepts

HINT **1. a. Listing** What are the parts of a volcano?
HINT **b. Sequencing** Describe the order of parts through which magma travels as it moves to the surface.
HINT **c. Relating Cause and Effect** As a volcano erupts, what force pushes magma out of a volcano onto the surface?
HINT **2. a. Identifying** What are the two main kinds of volcanic eruptions?
HINT **b. Explaining** What properties of magma help to determine the type of eruption?
HINT **c. Inferring** What do lava flows made of pahoehoe and aa indicate about the type of volcanic eruption that occurred?

3. a. Naming What are the three stages of volcanic activity? HINT
b. Predicting Which is more likely to be dangerous—a volcano that erupts frequently or a volcano that has been inactive for a hundred years? Why? HINT

Writing in Science

Interview You are a television news reporter who will be interviewing a geologist. The geologist has just returned from studying a nearby volcano that may soon erupt. Write the questions that you would ask. Be sure to ask about the evidence that an eruption is coming, the type of eruption expected, and any hazards that will result. Write an answer you expect for each question.

Section 3

Volcanic Landforms

CALIFORNIA Standards Focus

S 6.1.f Students know how to explain major features of California geology (including mountains, faults, and volcanoes) in terms of plate tectonics.

S 6.7.g Interpret events by sequence and time from natural phenomena (e.g., the relative age of rocks and intrusions).

- What landforms do lava and ash create?
- How does magma that hardens beneath the surface create landforms?

Key Terms

- shield volcano
- cinder cone
- composite volcano
- caldera
- volcanic neck
- dike
- sill
- intrusion
- batholith

Lab zone Standards Warm-Up

How Can Volcanic Activity Change Earth's Surface?

1. Use tape to secure the neck of a balloon over one end of a straw.
2. Place the balloon in the center of a box with the straw protruding.
3. Partially inflate the balloon.
4. Put damp sand on top of the balloon until it is covered.
5. Slowly inflate the balloon more. Observe what happens to the surface of the sand.

Think It Over

Making Models This activity models one of the ways in which volcanic activity can cause a mountain to form. What do you think the sand represents? What does the balloon represent?

Volcanoes have created some of Earth's most spectacular landforms. The perfect cone of Mount Fuji in Japan, shown in Figure 11, is famous around the world.

For much of Earth's history, volcanic activity on and beneath the surface has built up Earth's land areas. Volcanic activity also formed the rock of the ocean floor. Some volcanic landforms arise when lava flows build up mountains and plateaus on Earth's surface. Other volcanic landforms are the result of the buildup of magma beneath the surface.

FIGURE 11
Mount Fuji
The snow-capped volcanic cone of Mount Fuji in Japan has long been a favorite subject for artists.

Landforms From Lava and Ash

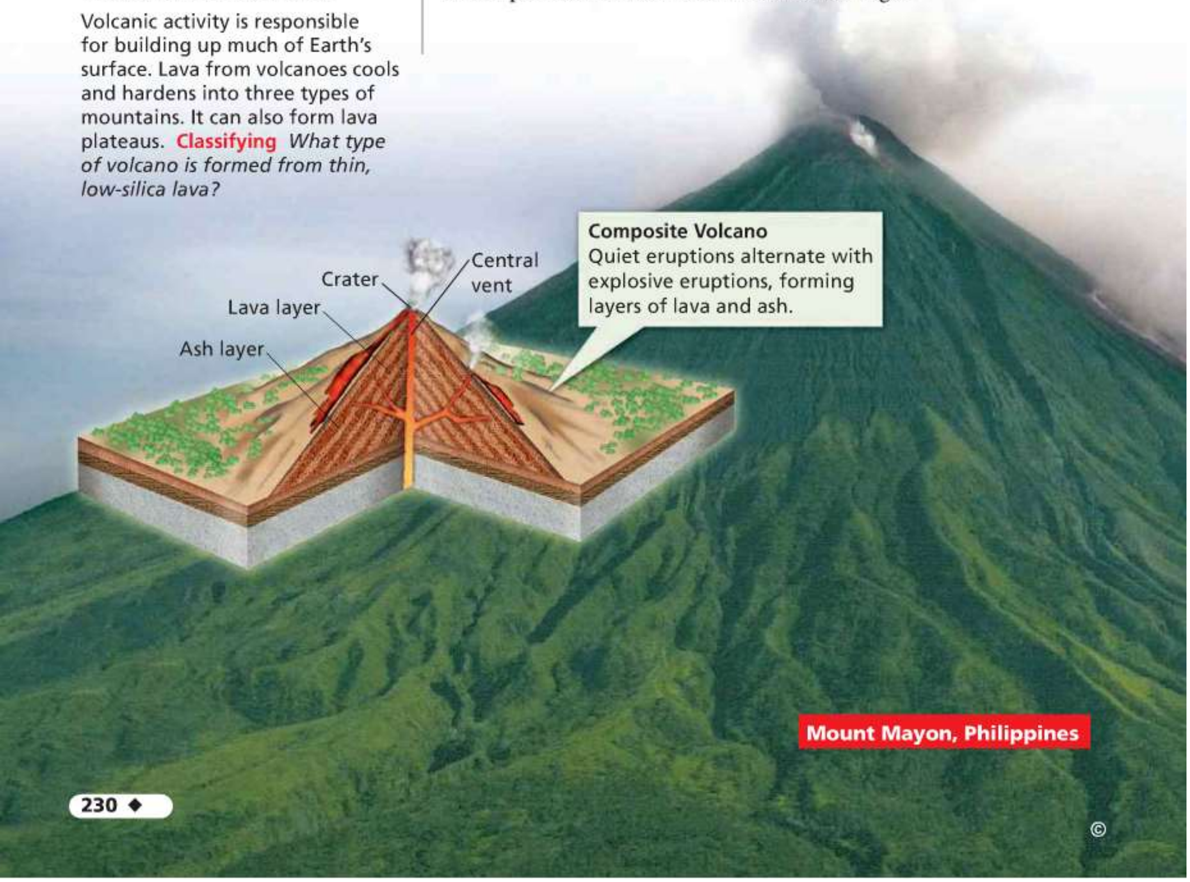
Volcanic eruptions create landforms made of lava, ash, and other materials. These landforms include shield volcanoes, cinder cone volcanoes, composite volcanoes, and lava plateaus. Look at Figure 12 to see these features. Another landform, called a caldera, results from the collapse of a volcanic mountain.

Shield Volcanoes At some places on Earth's surface, thin layers of lava pour out of a vent and harden on top of previous layers. Such lava flows gradually build a wide, gently sloping mountain called a **shield volcano.** Shield volcanoes created the Hawaiian Islands and the Medicine Lake volcano in northern California.

Cinder Cone Volcanoes If a volcano's lava is high in silica, it may produce ash, cinders, and bombs. These materials build up around the vent in a steep, cone-shaped hill or small mountain called a **cinder cone.** For example, Paricutín in Mexico erupted in 1943 in a farmer's cornfield. The volcano built up a cinder cone about 400 meters high.

FIGURE 12
Volcanic Mountains

Volcanic activity is responsible for building up much of Earth's surface. Lava from volcanoes cools and hardens into three types of mountains. It can also form lava plateaus. **Classifying** *What type of volcano is formed from thin, low-silica lava?*



Composite Volcanoes Sometimes, lava flows alternate with explosive eruptions of ash, cinder, and bombs. The result is a composite volcano. **Composite volcanoes** are tall, cone-shaped mountains in which layers of lava alternate with layers of ash. Examples include Mount Fuji in Japan and Mount Shasta and Lassen Peak in California.

Lava Plateaus Some eruptions of lava form high, level areas called lava plateaus. First, lava flows out of several long cracks, or fissures, in an area. The thin, runny lava travels far before cooling and solidifying. Again and again, floods of lava flow on top of earlier floods. After millions of years, these layers of lava can form high plateaus. Examples include the Columbia Plateau in Washington, Oregon, and Idaho, and the Modoc Plateau in northeastern California.

Video Field Trip
Discovery Channel School
Volcanoes

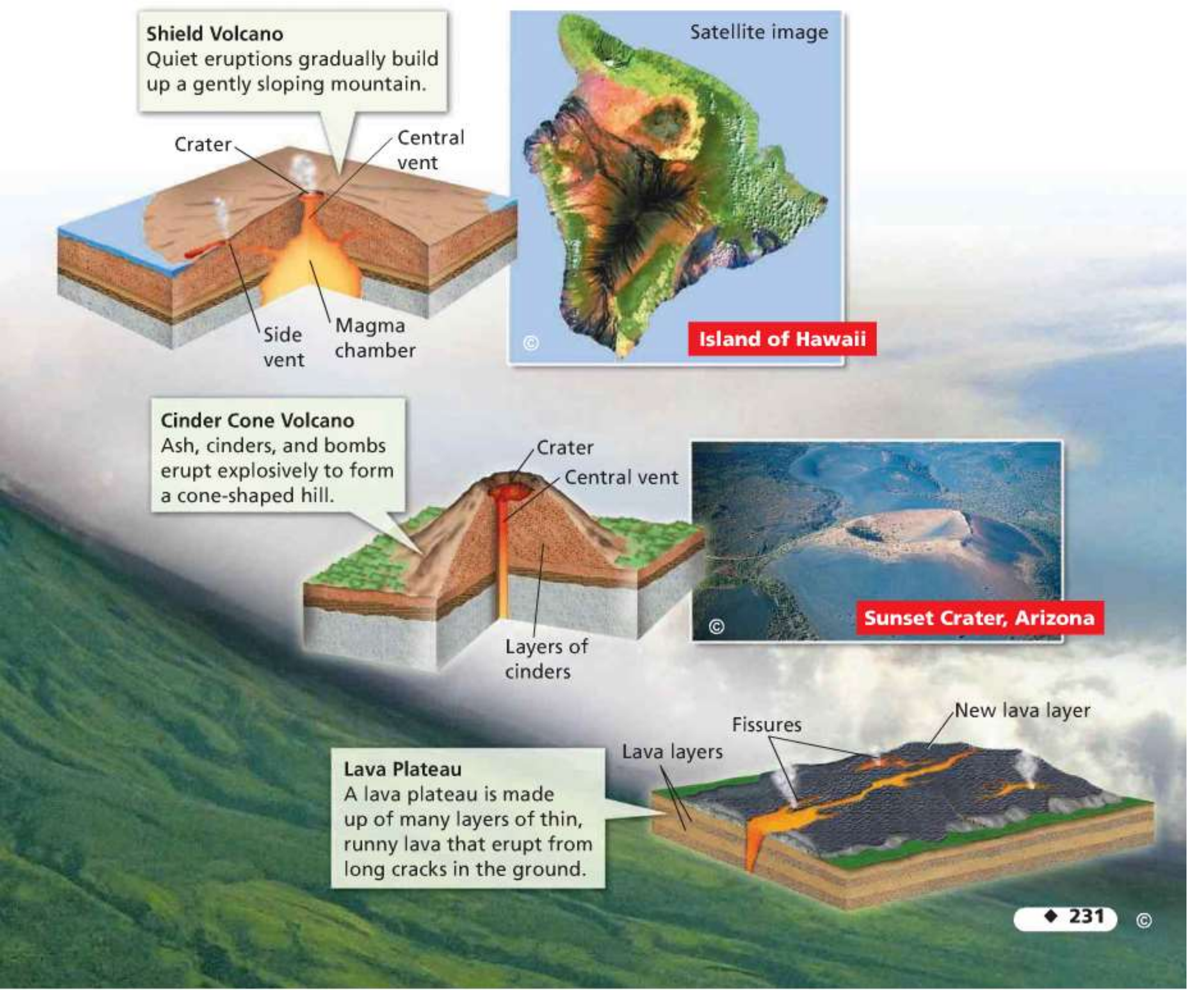
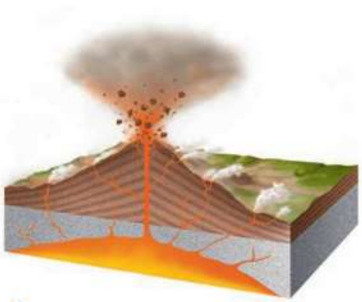
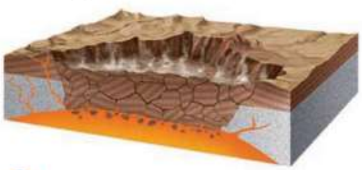


FIGURE 13
How a Caldera Forms
Today, Crater Lake (right) fills an almost circular caldera. A caldera forms when a volcano's magma chamber empties and the roof of the chamber collapses.



1 The top of a composite volcano explodes. Lava flows partially empty the magma chamber.



2 The roof of the magma chamber collapses, forming a caldera.

3 Later, a small cinder cone forms in the caldera, which partly fills with water.

Calderas The huge hole left by the collapse of a volcanic mountain is called a **caldera** (kal DAIR uh). The hole is filled with the pieces of the volcano that have fallen inward, as well as some lava and ash.

How does a caldera form? Enormous eruptions may empty the main vent and the magma chamber beneath a volcano. The mountain becomes a hollow shell. With nothing to support it, the top of the mountain collapses inward, forming a caldera.

In Figure 13 you can see steps in the formation of Crater Lake, a caldera in Oregon. Crater Lake formed about 7,700 years ago when a huge explosive eruption partly emptied the magma chamber of a volcano called Mount Mazama. When the volcano exploded, the top of the mountain was blasted into the atmosphere. The caldera that formed then filled with water from rain and snow.

In California, the Long Valley caldera formed after a huge eruption about 730,000 years ago. Geologists have detected the release of carbon dioxide gas and earthquakes centered near the caldera. These events are signs that volcanic eruptions might someday occur in the same area.

Soils From Lava and Ash Why would anyone live near an active volcano? People often settle close to volcanoes to take advantage of the fertile volcanic soil. The lava, ash, and cinders that erupt from a volcano are initially barren. Over time, however, the hard surface of the lava breaks down to form soil. When volcanic ash breaks down, it releases potassium, phosphorus, and other substances that plants need. As soil develops, plants are able to grow. Some volcanic soils are among the richest soils in the world. Rich soil is fertile, or able to support plant growth.

Reading Checkpoint **How are volcanic soils important?**

Landforms From Magma

Sometimes magma forces its way through cracks in the upper crust, but fails to reach the surface. There the magma cools and hardens into rock. Over time, the forces that wear away Earth's surface—such as flowing water, ice, or wind—may strip away the layers above the hardened magma and finally expose it. **Features formed by magma include volcanic necks, dikes, sills, and batholiths.**

Volcanic Necks A volcanic neck looks like a giant tooth stuck in the ground. A **volcanic neck** forms when magma hardens in a volcano's pipe. The softer rock around the pipe wears away, exposing the hard rock of the volcanic neck. Ship Rock in New Mexico, shown in Figure 14, is a volcanic neck.

Dikes and Sills Magma can force its way across or between rock layers. Magma that forces itself across rock layers hardens into a **dike.** Sometimes, a dike can be seen slanting through bedrock along a highway cut. When magma squeezes between horizontal layers of rock, it forms a **sill.**

Dikes and sills are examples of igneous intrusions. An **intrusion** forms when magma hardens underground to form igneous rock. An intrusion is always younger than the rocks around it.

Go Online SCI LINKS NSTA

For: Links on volcanic effects
Visit: www.SciLinks.org
Web Code: scn-1034

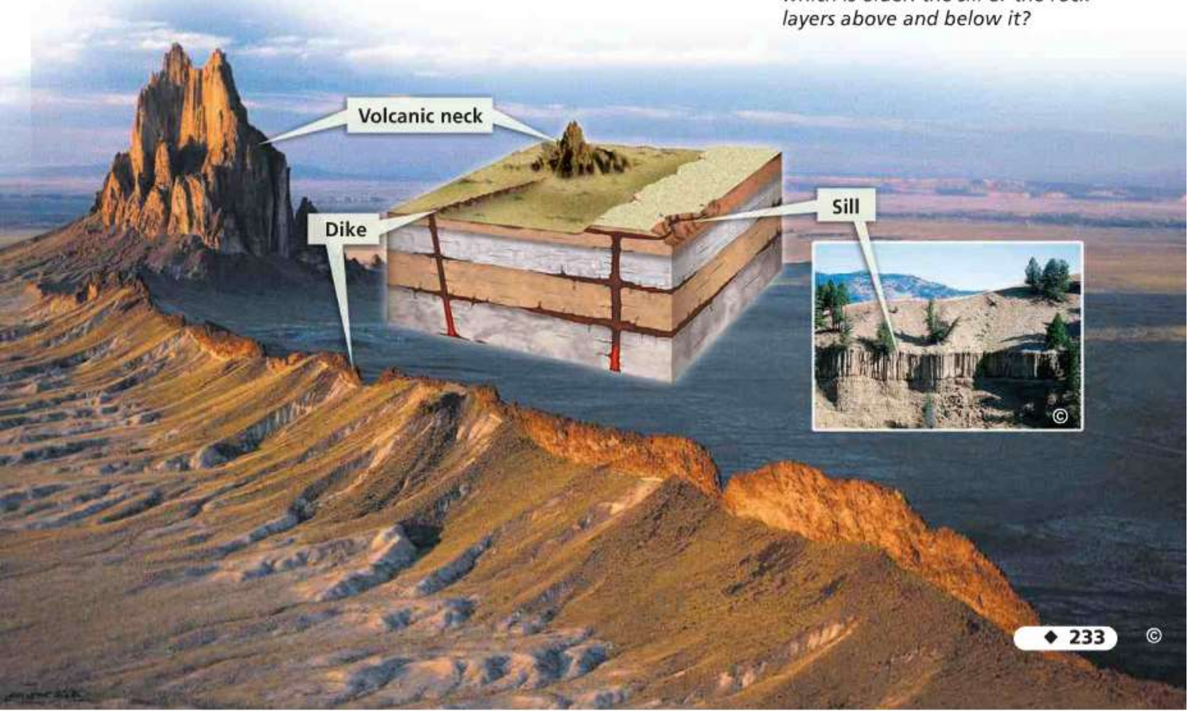


FIGURE 14
Volcanic Necks, Dikes, and Sills Magma that hardens beneath the surface may form volcanic necks, dikes, and sills. A dike extends outward from Ship Rock, a volcanic neck in New Mexico. **Applying Concepts** *In the photograph of the sill below, which is older: the sill or the rock layers above and below it?*

FIGURE 15
Batholiths
Several large batholiths form the core of mountain ranges in western North America, including the Sierra Nevada, shown here.

Batholiths Large rock masses called batholiths form the core of many mountain ranges. A **batholith** (BATH uh lith) is a mass of rock formed when a large body of magma cools inside the crust. The map in Figure 15 shows just how big batholiths really are. The Sierra Nevada batholith extends for roughly 600 kilometers along the eastern side of California. The photograph shows how a batholith looks when the layers of rock above it have worn away.

Section 3 Assessment

S 6.1.f, 6.7.g; E-LA: Reading 6.1.4, Writing 6.2.2

Vocabulary Skill Use Clues to Determine Meaning Reread the paragraphs under the heading Calderas. Find clues for a definition, an explanation, and an example of a caldera.

Reviewing Key Concepts

HINT
1. a. **Identifying** What are the three main types of volcanoes?

HINT
b. **Comparing and Contrasting** Compare the three types of volcanic mountains in terms of shape, type of eruption, and the materials that make up the volcano.

HINT
2. a. **Listing** What features form as a result of magma hardening beneath Earth's surface?

HINT
b. **Explaining** What are two ways in which mountains can form as a result of magma hardening beneath Earth's surface?

HINT
c. **Predicting** After millions of years, what landform forms from hardened magma in the pipe of an extinct volcano?

HINT
3. a. **Listing** What are some features found in areas of geothermal activity?

HINT
b. **Relating Cause and Effect** What causes a geyser to erupt?

Writing in Science

Explaining a Process Write an explanation of the process that formed Crater Lake. In your answer, include the type of volcanic mountain and eruption involved, as well as the steps in the process. (*Hint:* Look at the diagram in Figure 13 before you write.)

Section 4

California Geology

CALIFORNIA **Standards Focus**

S 6.1.f Students know how to explain major features of California geology (including mountains, faults, and volcanoes) in terms of plate tectonics.

How does plate tectonics help to explain features of California's geology?

Key Terms

- basin
- Central Valley

Lab zone Standards Warm-Up

How Do Plate Motions Affect California?

1. Look at the map of plate boundaries in Figure 17 on page 236. Study the map and the map key.
2. What are the names of the plates that make up California and the nearby part of the Pacific Ocean? Write the names of the plates in your notebook.
3. Determine what types of plate boundaries are found in or near California. Write the types of boundaries in your notebook.

Think It Over

Relating Cause and Effect Recall that there are volcanoes in northern California. Which feature on the map causes the volcanoes there? Explain.

If you flew in an airplane across the Mojave Desert, you might spot Amboy Crater. This extinct cinder cone would be easy to see—it's nearly half a kilometer across. Why is there a volcano here? Plate movement caused the crust to stretch and crack, allowing magma to reach the surface.

Many volcanic landforms dot the California landscape. But volcanoes are only one type of geologic feature that makes up a landscape.

Plate Tectonics and California

You have probably seen many maps of California. Plate tectonics helps to explain the geologic features on those maps.

The movements of the Pacific and North American plates produced California's major geological features. These features include faults, volcanoes, mountain ranges, and basins. These features took shape over millions of years.

FIGURE 16
Amboy Crater
Amboy Crater formed in the Mojave Desert about 10,000 years ago.

FIGURE 17
Plate Tectonics and California
The movements of three plates have shaped the geologic features of California over millions of years.
Predicting *What will happen to the Baja peninsula as sea-floor spreading occurs in the nearby Gulf of California?*

Faults Faults are often found along or near the boundaries of plates. As you can see in Figure 17, the Pacific and North American plates slide past each other along the San Andreas fault. They push and pull on the crust with enormous force. The crust breaks, forming many other faults, shown in Figure 18.

Volcanoes In the Pacific Ocean north of California, the Juan de Fuca plate is being subducted beneath the North American plate. Mount Shasta and Lassen Peak in northern California are volcanoes that resulted from this process.

Mountain Ranges Plate motion provides the force that pushes up California's mountains. The Sierra Nevada began to form several million years ago as plate movements pushed up a batholith. Plate motions folded the crust to push up the northern Coast Ranges. The Transverse Ranges formed as plate motions rotated a block of crust and squeezed it upward.

Basins Plate movements sometimes cause the crust to warp, or bend, downward. The result is a basin. A **basin** is a broad, bowl-shaped valley. For example, the **Central Valley** of California is a huge basin with the Sierras and Coast Ranges on either side. As these mountains rose, the crust forming the Central Valley's floor was bent downward. Slowly, a thick layer of sediment built up on the valley floor.

Millions of years ago, some of California's basins slowly sank below sea level. Later, plate motions pushed the crust above sea level again.

Section 4 Assessment

S 6.1.f, E-LA: Reading 6.1.4

Vocabulary Skill Use Clues to Determine Meaning
Reread the paragraphs under the heading Basins. Find clues for a definition, an explanation, and an example of a basin.

Reviewing Key Concepts

HINT
1. a. **Listing** What four features of California geology does plate tectonics explain?

HINT
b. **Explaining** How does the San Andreas fault help to explain why there are so many other faults in California?

HINT
c. **Predicting** Los Angeles lies on the Pacific plate. San Jose lies on the North American plate. How will the distance between the two cities change over millions of years?

Lab zone At-Home Activity

Modeling California
Use plastic putty to make a model of California, showing the state's major geologic features. Use one color of putty for the part of the state that is on the Pacific plate and another color for the part that is on the North American plate. Explain your model to family members.

California's Geologic Features

FIGURE 18
Many geologic processes worked together to form California's landscape of volcanoes, faults, mountain ranges, and basins.

1 Volcanoes

Mount Shasta formed as a result of the subduction of the Juan de Fuca plate.

2 Faults

The San Andreas fault slices through the San Francisco peninsula.

3 Mountain Ranges

Plate motions pushed up the Transverse Range in California.

4 Basins

Like the Central Valley, the Los Angeles basin formed where the crust was bent downward.

Lab zone **Skills Lab**
Guided Inquiry

S 6.1.d

Gelatin Volcanoes

Materials

unflavored gelatin mold in bowl

aluminum pizza pan with holes punched at 2.5-cm intervals

3 small cardboard oatmeal boxes

tray or shallow pan and rubber gloves

red food coloring, plastic cup, and water

plastic syringe, 10 cc, and plastic knife

unlined paper

Problem

How does magma move inside a volcano?

Skills Focus

developing hypotheses, making models, observing

Procedure

1. Before magma erupts as lava, how does it travel up from underground magma chambers? Record your hypothesis.
2. Remove the gelatin from the refrigerator. Loosen the gelatin from its container by briefly placing the container of gelatin in a larger bowl of hot water.
3. Place the pizza pan over the gelatin so the mold is near the center of the pizza pan. While holding the pizza pan against the top of the mold, carefully turn the mold and the pizza pan upside down.
4. Carefully lift the bowl off the gelatin mold to create a gelatin volcano.
5. Place the pizza pan with the gelatin mold on top of the oatmeal boxes as shown below.
6. Mix the red food coloring and water in the plastic cup. Then fill the syringe with "magma" (the red water). Remove air bubbles from the syringe by holding it upright and squirting out a small amount of water.
7. Insert the tip of the syringe through a hole in the pizza pan near the center of the gelatin volcano. Inject the magma into the gelatin very slowly. Observe what happens to the magma.
8. Repeat steps 6 and 7 as many times as possible. Observe the movement of the magma each time. Note any differences in the direction the magma takes when the syringe is inserted into different parts of the gelatin volcano. Record your observations.

Data Table			
Test	Initial Location of Magma	Position and Shape of Magma Bodies	Other Observations
1.			
2.			
3.			
4.			

9. Look down on your gelatin volcano from above. Make a sketch of the positions and shapes of the magma bodies. Label your drawing "Top View."
10. Carefully use a knife to cut your volcano in half. Separate the pieces and examine the cut surfaces for traces of the magma bodies.
11. Sketch the positions and shapes of the magma bodies on one of the cut faces. Label your drawing "Cross Section."

Analyze and Conclude

1. **Observing** Describe how the magma moved through your model. Did the magma move straight up through the center of your model volcano or did it branch off in places? Explain why you think the magma moved in this way.
2. **Developing Hypotheses** What knowledge or experience did you use to develop your hypothesis? How did the actual movement compare with your hypothesis?
3. **Inferring** How would you explain any differences in the direction the magma flowed when the syringe was inserted in different parts of the gelatin volcano?
4. **Making Models** How does what you observed in your model compare to the way magma moves through real volcanoes? How could you change your model to be more like a real volcano?
5. **Communicating** Prepare your model as a display to teach other students about volcanoes. Make a list of the volcanic features in your model. For each feature, write a description of how the feature would form in a real volcano.

More to Explore

Plan to repeat the investigation using a mold made of two layers of gelatin. Before injecting the magma, develop a hypothesis about the effect of layering on the movement of magma. Record your observations to determine if your hypothesis was correct. What volcanic feature is produced by this version of the model? Can you think of other volcanic features that you could model using gelatin layers? *Obtain your teacher's permission before carrying out your investigation.*

An eruption of Mount Kilauea, Hawaii

Chapter 6 Study Guide

The BIG Idea Volcanic eruptions result from plate motions and produce landforms such as volcanic mountains and lava plateaus.

1 Volcanoes and Plate Tectonics

Key Concepts S 6.1.e

- Volcanic belts form along the boundaries of Earth's plates.
- A volcano forms above a hot spot when magma erupts through the crust and reaches the surface.

Key Terms

volcano
magma
lava
Ring of Fire
island arc
hot spot

2 Volcanic Eruptions

Key Concepts S 6.1.d, 6.2.d

- When a volcano erupts, the force of the expanding gases pushes magma from the magma chamber through the pipe until it flows or explodes out of the vent.
- Geologists classify volcanic eruptions as quiet or explosive.
- Geologists often use the terms *active, dormant,* or *extinct* to describe a volcano's stage of activity.

Key Terms

magma chamber
pipe
vent
lava flow
crater
silica
pyroclastic flow
dormant
extinct
geyser

3 Volcanic Landforms

Key Concepts S 6.1.f, 6.7.g

- Volcanic eruptions create landforms made of lava, ash, and other materials. These landforms include shield volcanoes, cinder cone volcanoes, composite volcanoes, and lava plateaus.
- Features formed by magma include volcanic necks, dikes, sills, and batholiths.

Key Terms

shield volcano
cinder cone
composite volcano
caldera
volcanic neck
dike
sill
batholith

4 California Geology

Key Concepts S 6.1.f

- The movements of the Pacific and North American plates produced California's major geological features. These features include faults, volcanoes, mountain ranges, and basins.

Key Terms

basin
Central Valley

Review and Assessment

Go Online PHSchool.com
For: Self-Assessment
Visit: PHSchool.com
Web Code: cfa-1030

Target Reading Skill

Create Outlines In your notebook, add details and definitions to your outline for Kinds of Volcanic Eruptions in Section 2.

Volcanic Eruptions
I. Kinds of Volcanic Eruptions A. Quiet Eruptions B. Explosive Eruptions

Reviewing Key Terms

Choose the letter of the best answer.

HINT **1.** Volcanoes found where two oceanic plates collide form a(n)
a. cinder cone. **b.** island arc.
c. hot spot. **d.** Ring of Fire.

HINT **2.** Magma becomes lava when it reaches a volcano's
a. geyser. **b.** magma chamber.
c. pipe. **d.** vent.

HINT **3.** Lava that forms smooth, ropelike coils when it hardens is called
a. aa.
b. silica.
c. pahoehoe.
d. pyroclastic flow.

HINT **4.** A volcanic mountain made up of volcanic ash, cinders, and bombs is called a
a. shield volcano.
b. cinder cone.
c. composite volcano.
d. caldera.

HINT **5.** The collapse of a volcano's magma chamber may produce a(n)
a. crater.
b. island arc.
c. caldera.
d. batholith.

6. A volcano that has not erupted for many years but might erupt again in the future is HINT
a. extinct.
b. dormant.
c. pyroclastic.
d. active.

7. Magma that hardens in a volcano's pipe forms a HINT
a. volcanic neck.
b. sill.
c. volcanic crater.
d. hot spot.

Complete the following sentences so that your answers clearly explain the key terms.

8. Far from plate boundaries, a volcano may form over a **hot spot,** which is __________ . HINT

9. An explosive eruption may produce a **pyroclastic flow,** which is ______________ . HINT

10. When magma that is high in silica erupts, it can form a **cinder cone,** which is _________ . HINT

11. A thin sheet of magma can harden underground to form a **dike,** which is _____ . HINT

12. Between California's Coast Ranges and the Sierra Nevada lies the **Central Valley,** which is _______ . HINT

13. In a volcanic area, underground water and steam can form a **geyser,** which is _______ . HINT

Writing in Science

Comparison Write a comparison of the three different kinds of volcanoes. Discuss the ways in which all three are similar and the ways in which they are different. Use the correct terms to describe each type of volcano.

Video Assessment
Discovery Channel School
Volcanoes

Review and Assessment

Checking Concepts

14. What is the Ring of Fire?

15. What process causes volcanoes to form along the mid-ocean ridge?

16. What are two ways volcanoes can form near converging plate boundaries?

17. What effect does temperature have on the characteristics of magma?

18. How does a shield volcano form?

19. Describe the three stages in the "life cycle" of a volcano.

20. Why can earthquakes be a warning sign that an eruption is about to happen?

21. What type of geologic feature is the Central Valley of California? How did it form?

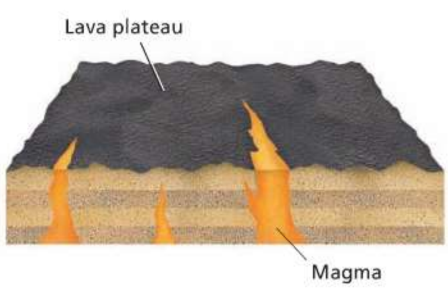
Thinking Critically

22. Predicting Is a volcanic eruption likely to occur on the East Coast of the United States? Explain your answer.

23. Comparing and Contrasting Compare the way in which an island arc forms with the way in which a hot spot volcano forms.

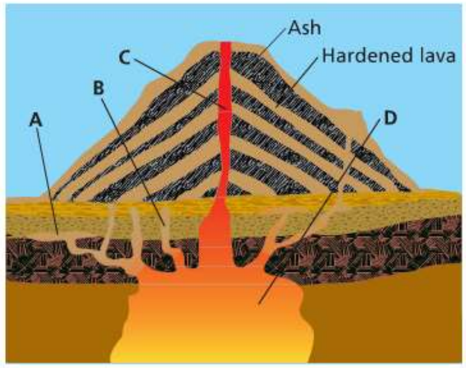
24. Making Generalizations How might a volcanic eruption affect the area around a volcano, including its plant and animal life?

25. Relating Cause and Effect Look at the diagram of a lava plateau below. Why doesn't the type of eruption that produces a lava plateau produce a volcanic mountain instead?



Applying Skills

Refer to the diagram to answer Questions 26–29.



26. Classifying What is this volcano made of? How do geologists classify a volcano made of these materials?

27. Developing Hypotheses What is the feature labeled A in the diagram? What is the feature labeled B? How do these features form?

28. Predicting What is the feature labeled C in the diagram? If this feature becomes plugged with hardened magma, what could happen to the volcano? Explain.

29. Inferring What is the feature labeled D in the diagram? What can you infer about this feature if the volcano becomes dormant?

Lab zone Standards Investigation

Performance Assessment Present your documentary about a volcanic region to your class. Evaluate how well your documentary presented the information you collected. As you watched the other documentaries, did you see any similarities between how people in different regions live with volcanoes?

CALIFORNIA
Standards Practice

Success Tracker™
Online at PHSchool.com

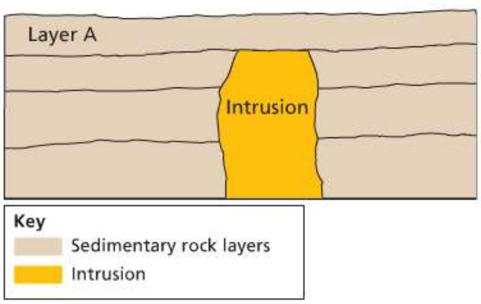
Choose the letter of the best answer.

1. A composite volcano is most likely to form
A above a hot spot.
B where an oceanic plate collides with a continental plate.
C along the mid-ocean ridge.
D along a rift valley. **S 6.1.e**

2. Mount Shasta is a composite volcano in northern California. Mount Shasta formed as a result of a
A hot spot.
B sliding plate boundary.
C spreading plate boundary.
D colliding plate boundary. **S 6.1.f**

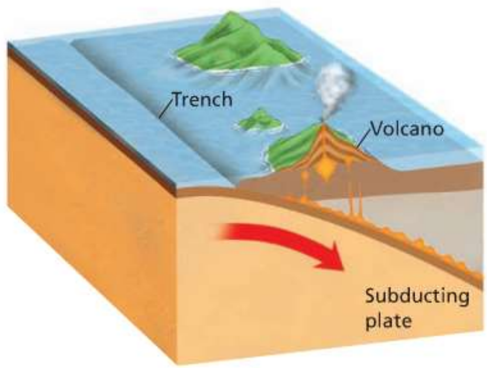
3. Which answer is a benefit that explains why people might live in the region around a volcano?
A A volcano removes trees.
B Volcanic eruptions are interesting to watch.
C Volcanic soil is good for growing crops.
D Volcanoes release various gases. **S 6.2.d**

4. Study the diagram below. Which answer best describes the age of the sedimentary rock layers relative to the intrusion?
A much younger
B older
C the same age
D slightly younger **S 6.7.g**



5. Magma that hardens between layers of rock forms a
A volcanic neck.
B dike.
C batholith.
D sill. **S 6.1.d**

6. The diagram below shows the formation of what volcanic feature?
A caldera
B island arc volcano
C hot spot
D mid-ocean ridge **S 6.1.e**



Apply the BIG Idea

7. A geologist was observing the area around a dormant volcano. She decided that this volcano must have had an explosive eruption. Describe the evidence geologists would use to make this decision. In your answer, discuss the properties of the magma and the types of rock that would result from an explosive eruption. **S 6.1.d**